Characterizing land surface phenologies in the highlands of Kyrgyzstan through synergistic use of Landsat and MODIS data

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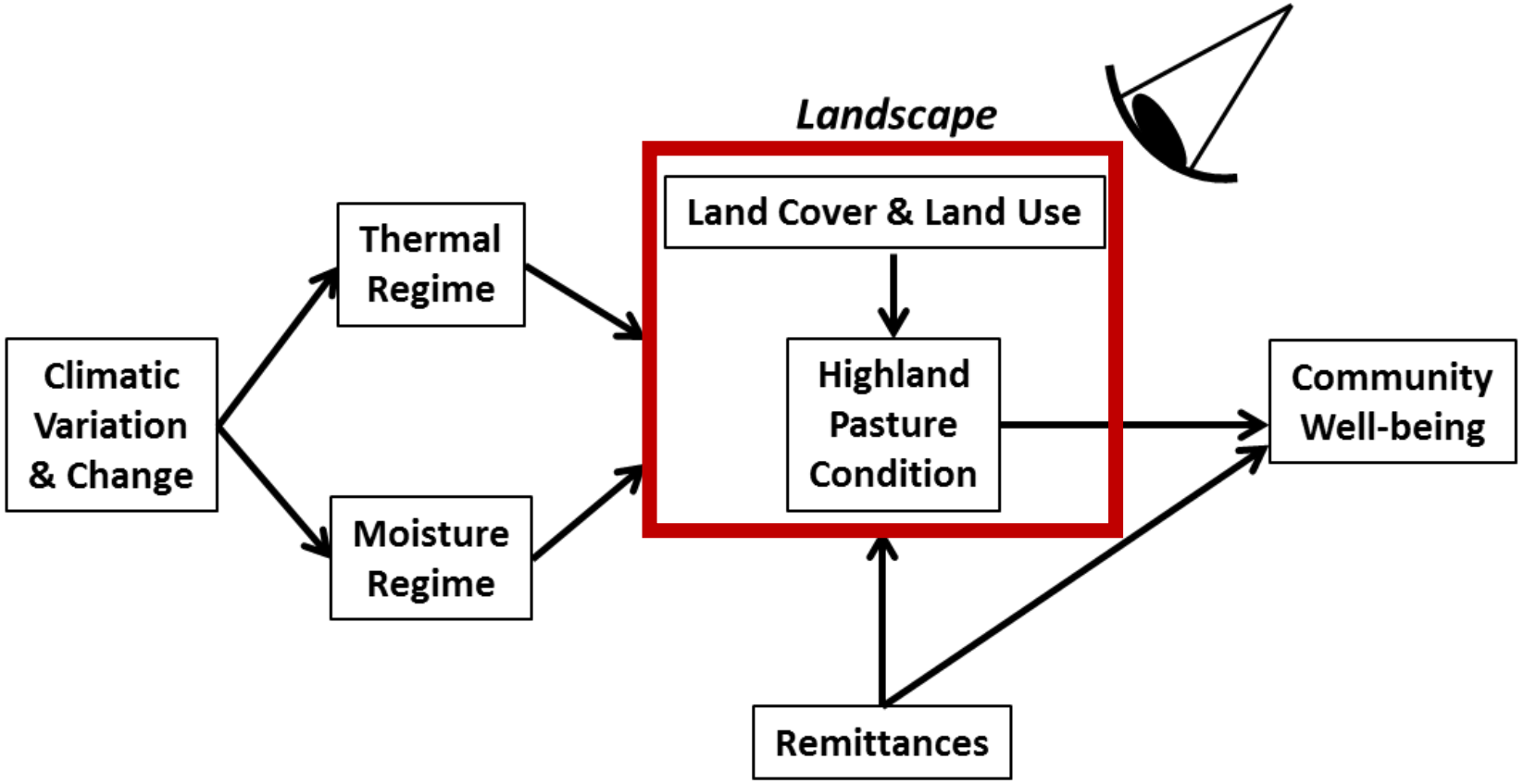
The Caucasus and Central Asia

https://en.wikipedia.org/wiki/Geostrategy_in_Central_Asia#/media/File:Caucasus_central_asia_political_map_2000.jpg

Land area of Kyrgyzstan (199,951 km^2) is slightly larger than South Dakota (199,730 km^2), but Kyrgyzstan is very mountainous (94%) and more populous (~6M vs. <1M).



Fundamental question: **Can the change of pasture condition can be detected through remote sensing and linked to community well-being through econometric and structural equation modeling?**

Ancillary question: **Can the drivers of change of pasture condition be addressed through remote sensing of land surface phenology (vegetation indices) and land surface seasonality (snow cover metrics)?**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Initial Synthesis

[I] Increasing temperatures reduce snow cover duration may shift the growing season earlier and extend it longer in high mountain pastures, but the increasing temperatures may also reduce seasonal forage production due to reduced soil moisture resulting from higher evapotranspiration.

[II] Increased remittances lead to increased livestock and more grazing pressures on nearby pastures, but may not have increased grazing in remote highland pastures since 1991, which, in turn, leads to the declined status of lower pastures nearby human settlements and improved status of more remote pastures at higher elevations.


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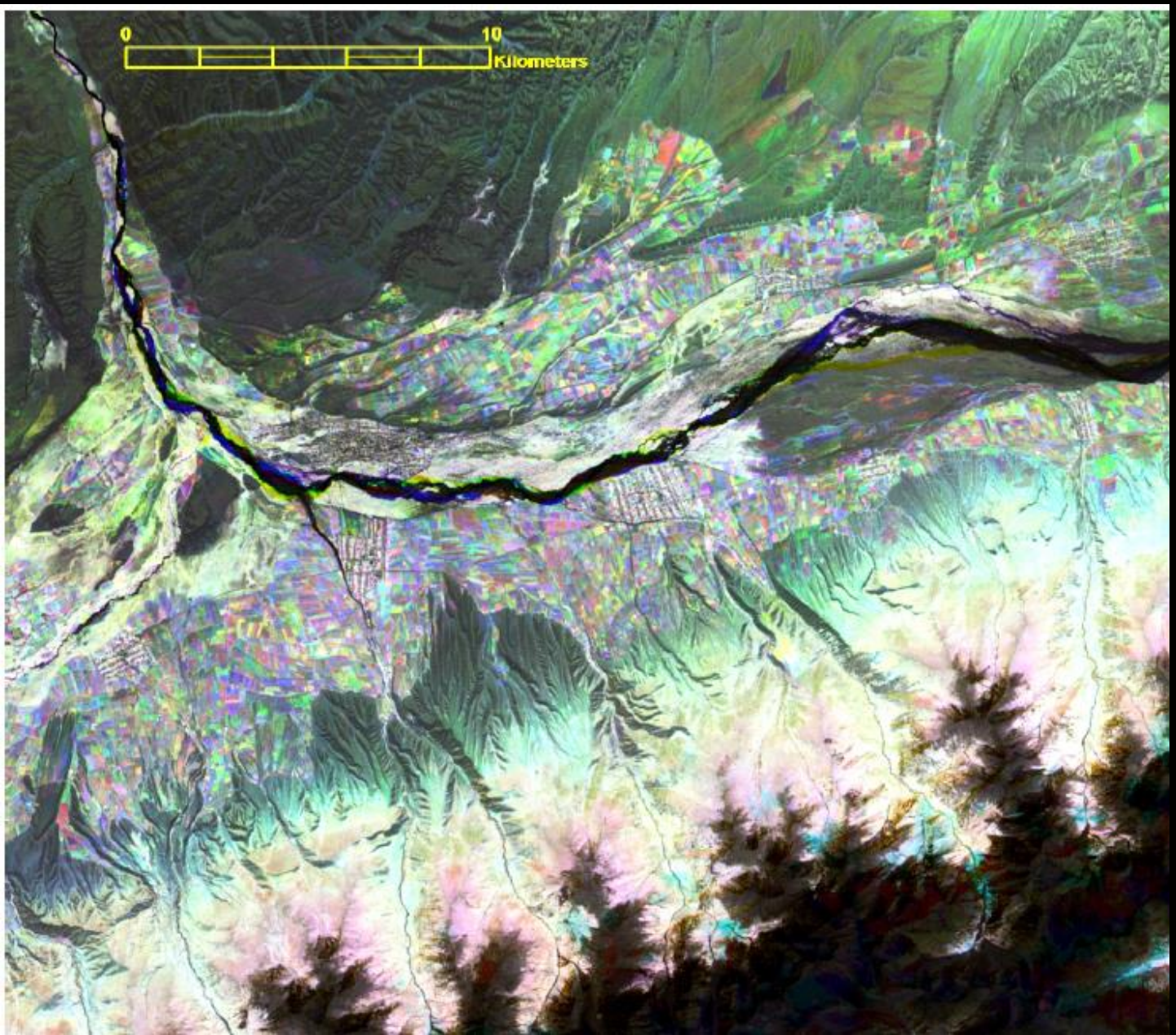
Livelihoods poised between cold and dry



NDVI composite of L5 TM & L7 ETM+ scenes:

23AUG2002 (L7)
02SEP2000 (L7)
06SEP2010 (L5)

Naryn oblast showing At-Bashi & surrounding villages on either bank of the At-Bashi River, just north of the At-Bashi Ridge in the Central Tien-Shan .

Persistent snow cover on the north-facing slopes of the At-Bashi Ridge appears dark (lower right).

Other dark areas indicate either open water (*e.g.*, river) or areas of persistently low vegetation (*e.g.*, drylands to the top left and barren slopes between the croplands and the vegetated slopes).

Phenology is the study of

i. the timing of recurring biological events,
ii. the causes of their timing,
iii. their relationship to biotic and abiotic forces, and
iv. the inter-relations among phases of the same or different species.

US/IBP Phenology Committee, 1973

Source: Lieth, H. 1974. Purposes of a phenology book. Pp 3-19. In: (H. Lieth, ed.) Phenology and Seasonality Modeling. New York: Springer-Verlag. 444 pp.

Some Useful Distinctions & Categories

- **Phenology: Biotic patterns :: Seasonality: Abiotic patterns**
  But seasonality can affect phenology and vice versa.
- **Land surface phenology is distinct from organismal phenology**: observing electromagnetic radiation at coarse spatial resolution results in a mixture of signals that combines biotic and abiotic components.
- **LSPs are the seasonal spatio-temporal patterns of the vegetated land surface.**
- **LSPs affect the timing and magnitude of energy and water exchanges between the land surface and the boundary layer.**

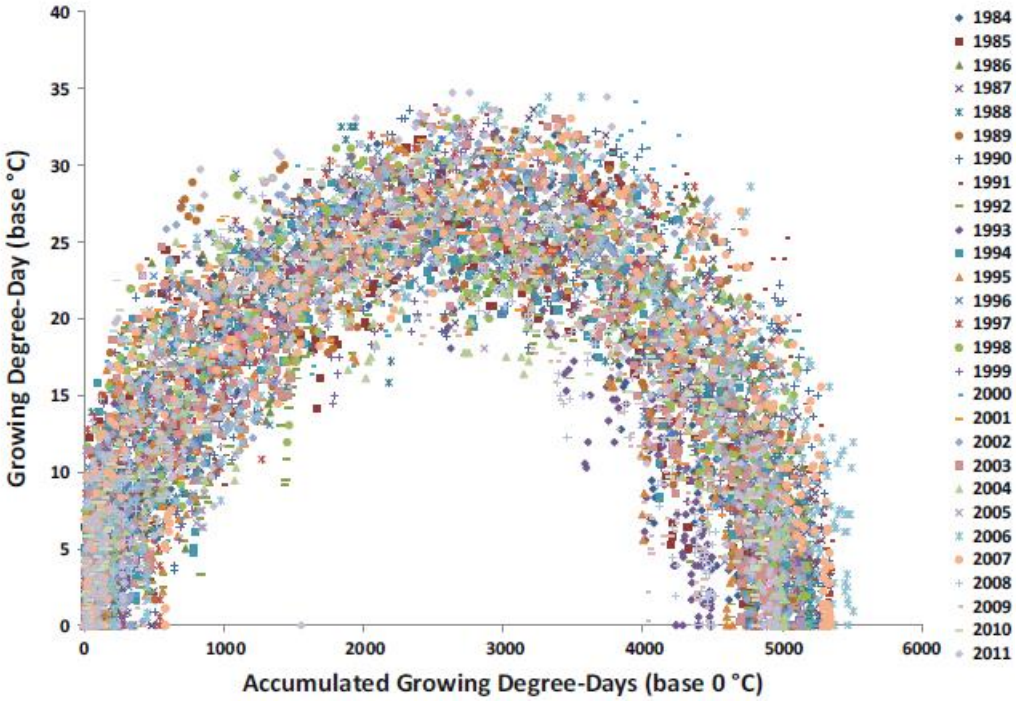
We track the progression of the growing season using **Accumulated Growing Degree-Days** (also known as **thermal time**) is a simple biometeorological variable that weights the passage of days by the quantity of "growing degrees" – that portion of the diel temperature range that is useful for plant growth, broadly construed.

The calculation of AGDD is straightforward:

(1) $AvgTemp_t = (MaxTemp_t + MinTemp_t)/2$

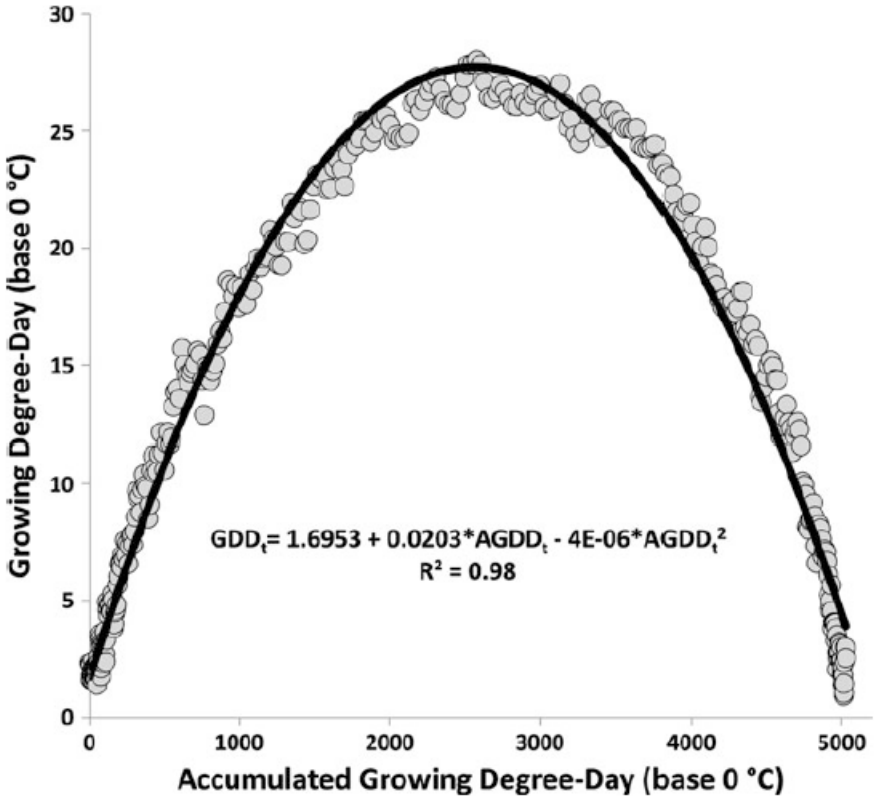
(2) $AGDD_t = AGDD_{t-1} + \max[(AvgTemp_t - Base),0]$

Base = 0 °C and accumulation resets 01JAN.



← Growing degree-days (base 0 °C) as a function of accumulated growing degree-days (AGDD) for Manhattan, KS 1984-2011

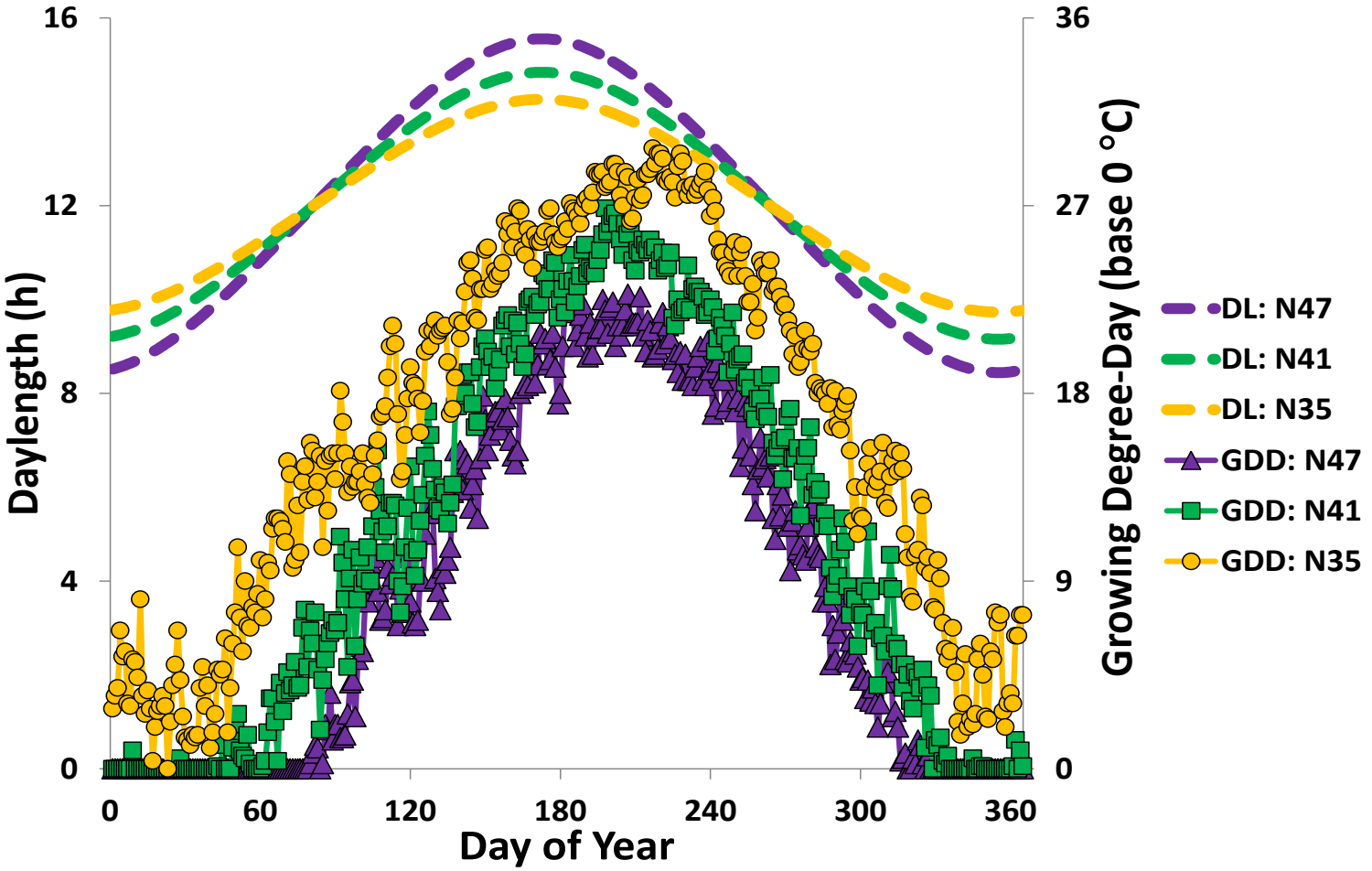
Mean GDD (base 0 °C) as a function of AGDD for Manhattan, KS 1984-2011 →



To build LSP models we want to take advantage of the natural clock of insolation at mid-latitudes.

Henebry GM. 2013. Phenologies of North American Grasslands and Grasses. In: (MD Schwartz, ed.) **Phenology: An Integrative Environmental Science, 2e**. Springer. Chapter 11, pp. 197-210.

Both insolation and growing degree-days exhibit simple shapes across the middle latitudes



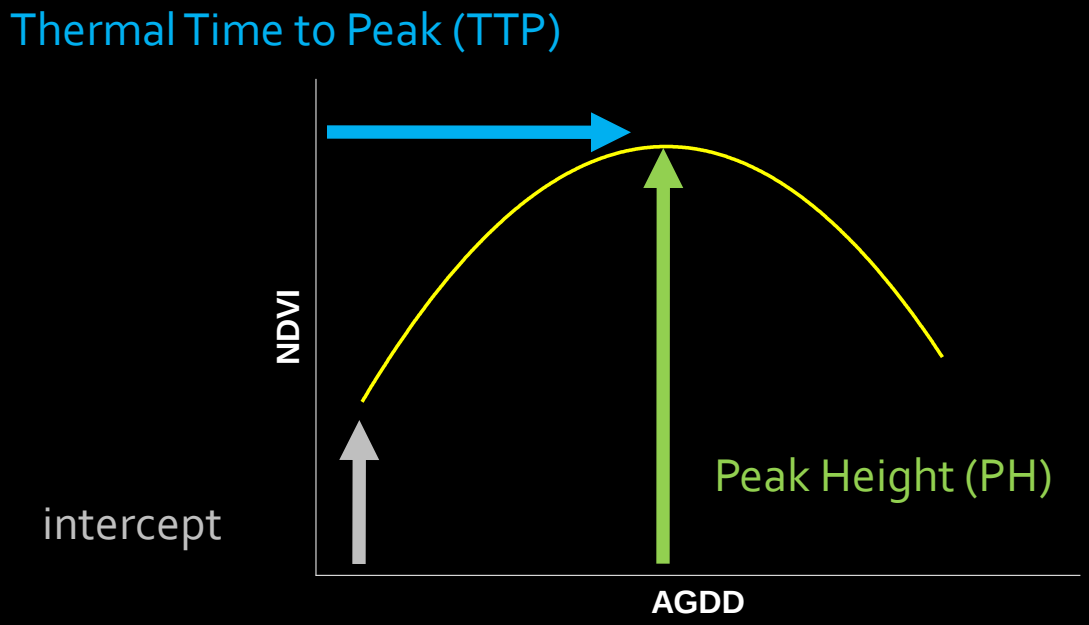
Henebry GM. 2013. Phenologies of North American Grasslands and Grasses. In: (MD Schwartz, ed.) **Phenology: An Integrative Environmental Science, 2e**. Springer. Chapter 11, pp. 197-210.

The Convex Quadratic (CxQ) LSP model links a VI (*e.g.*, NDVI, WDRVI, EVI) to the temporal progression of accumulated growing degree-days (AGDD) and it has been successfully applied to a variety of settings and scales.

$$NDVI = \alpha + \beta * AGDD - \gamma * AGDD^2$$

$$PH = \alpha - (\beta^2 / 4\gamma)$$

$$TTP = -\beta / 2\gamma$$

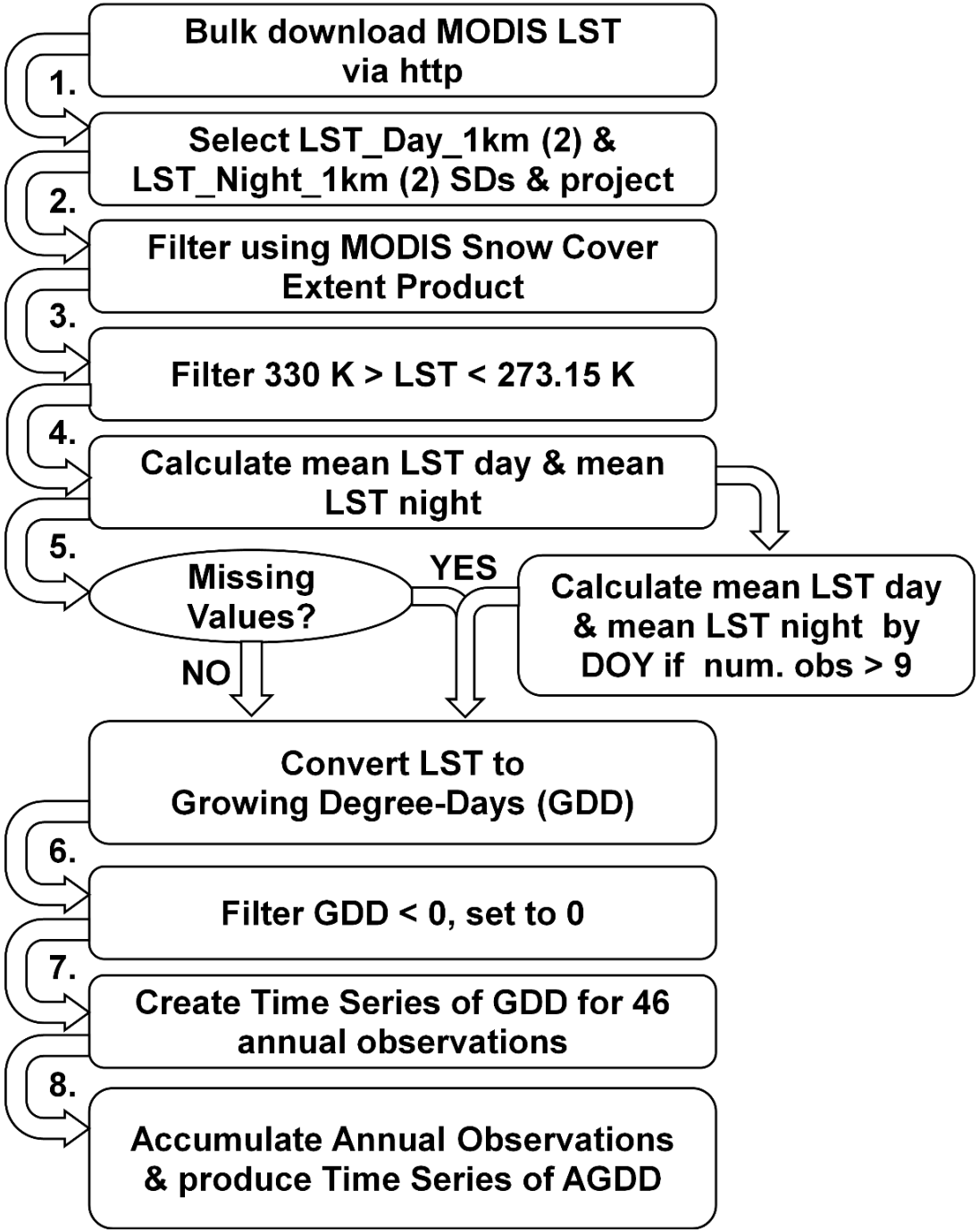


NDVI from Landsat
AGDD from MODIS

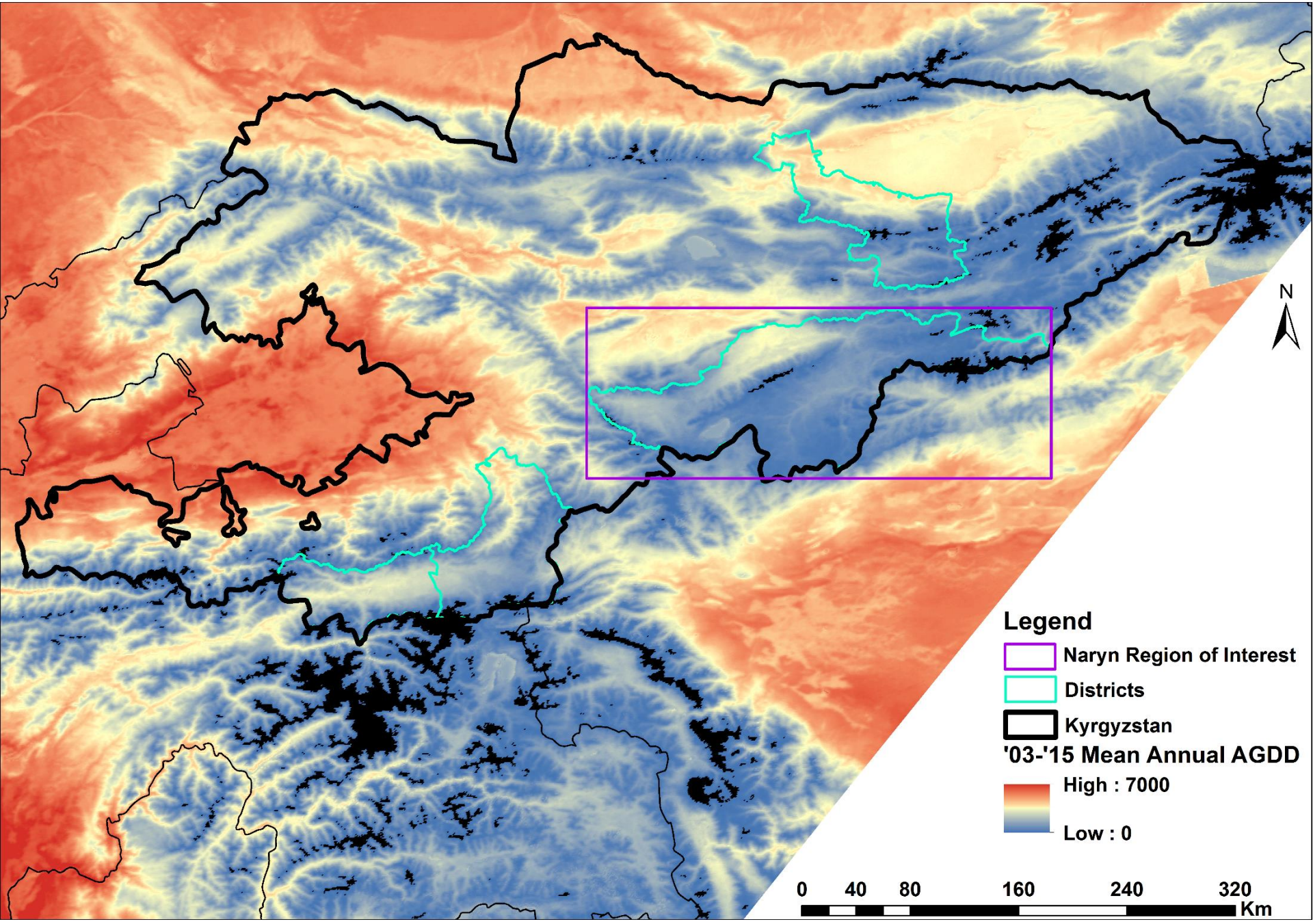
Processing chain for converting MODIS LST into Accumulated Growing Degree-Days (AGDD)

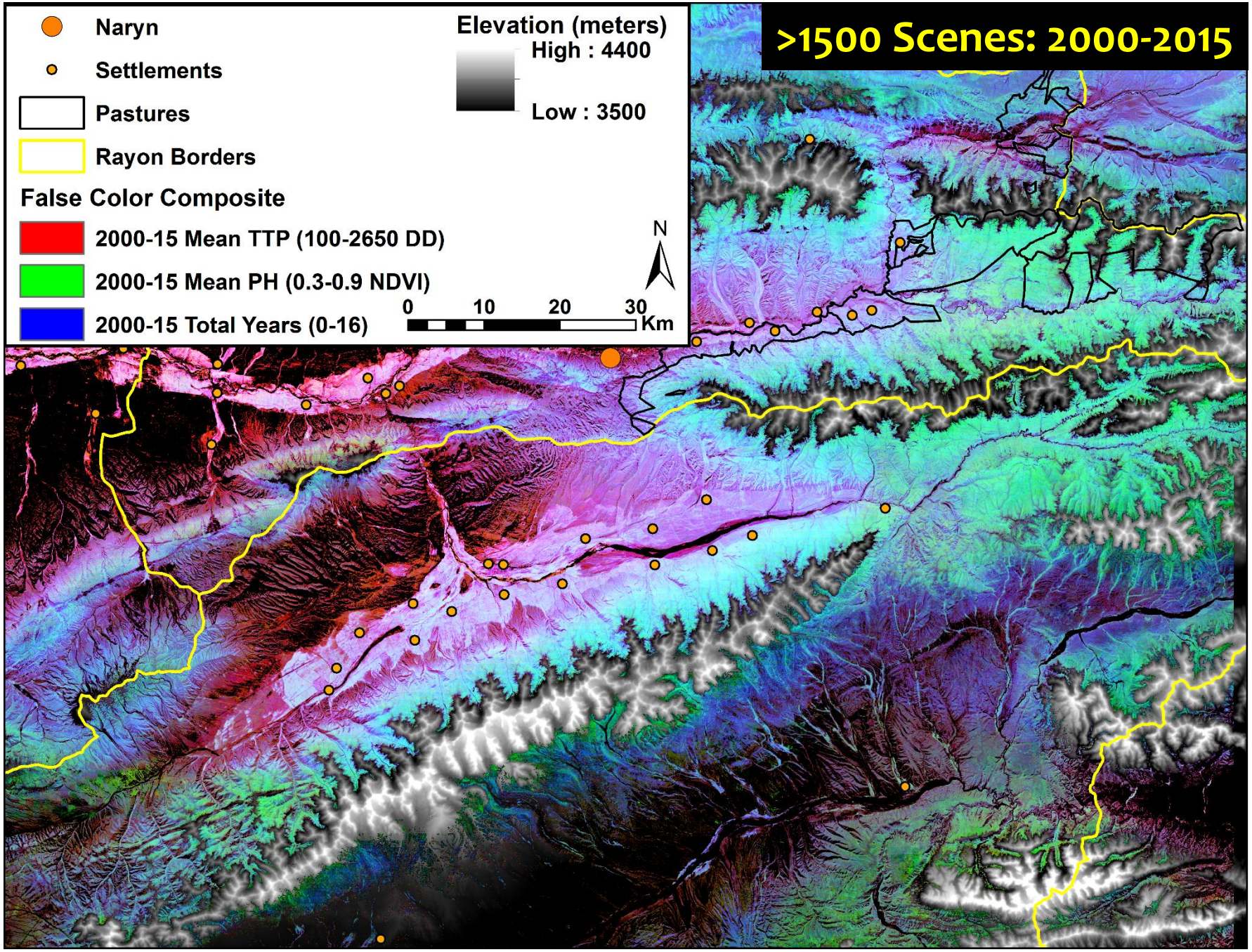
GDD = max [(AvgTemp-BaseTemp), 0]

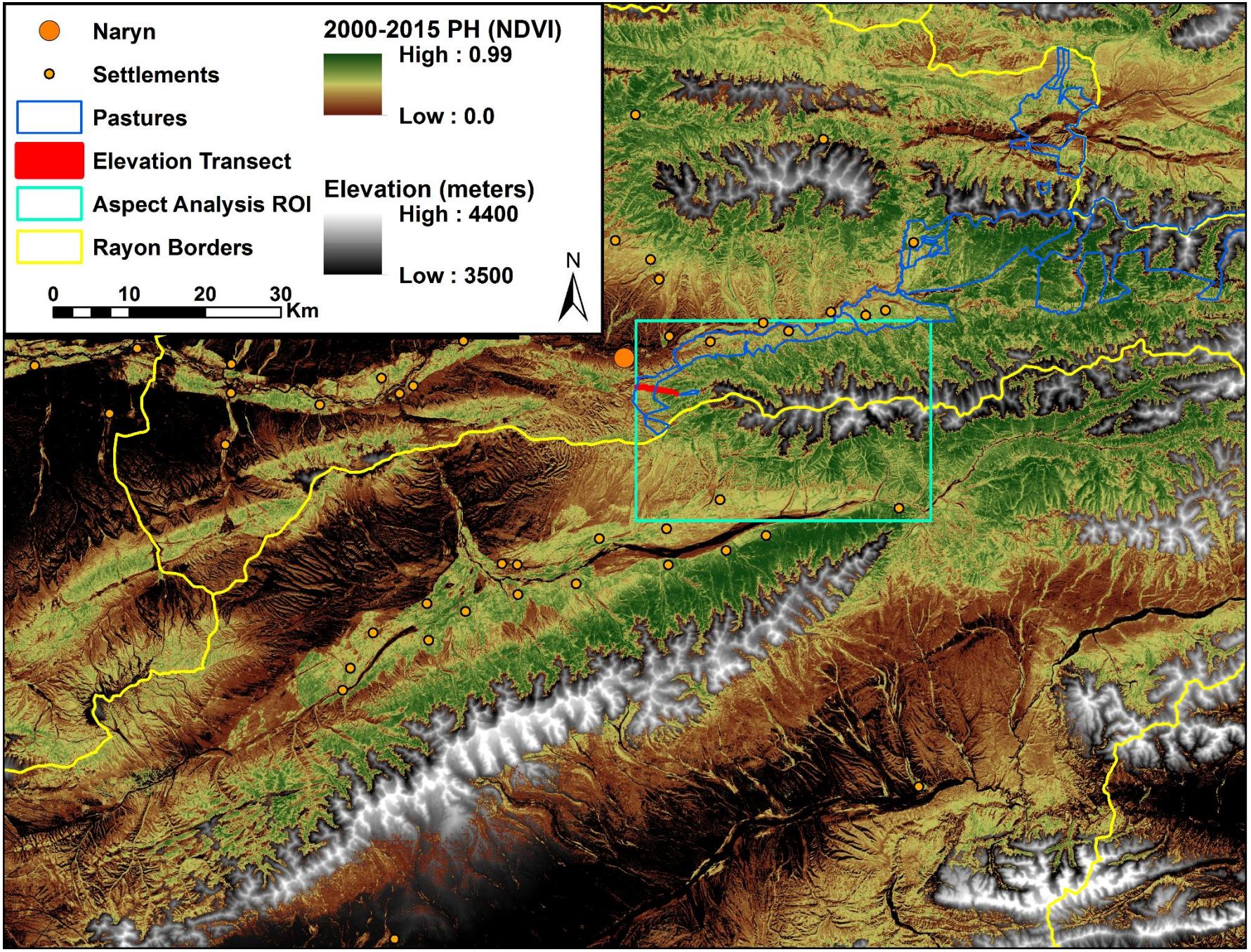
BaseTemp = 0 °C

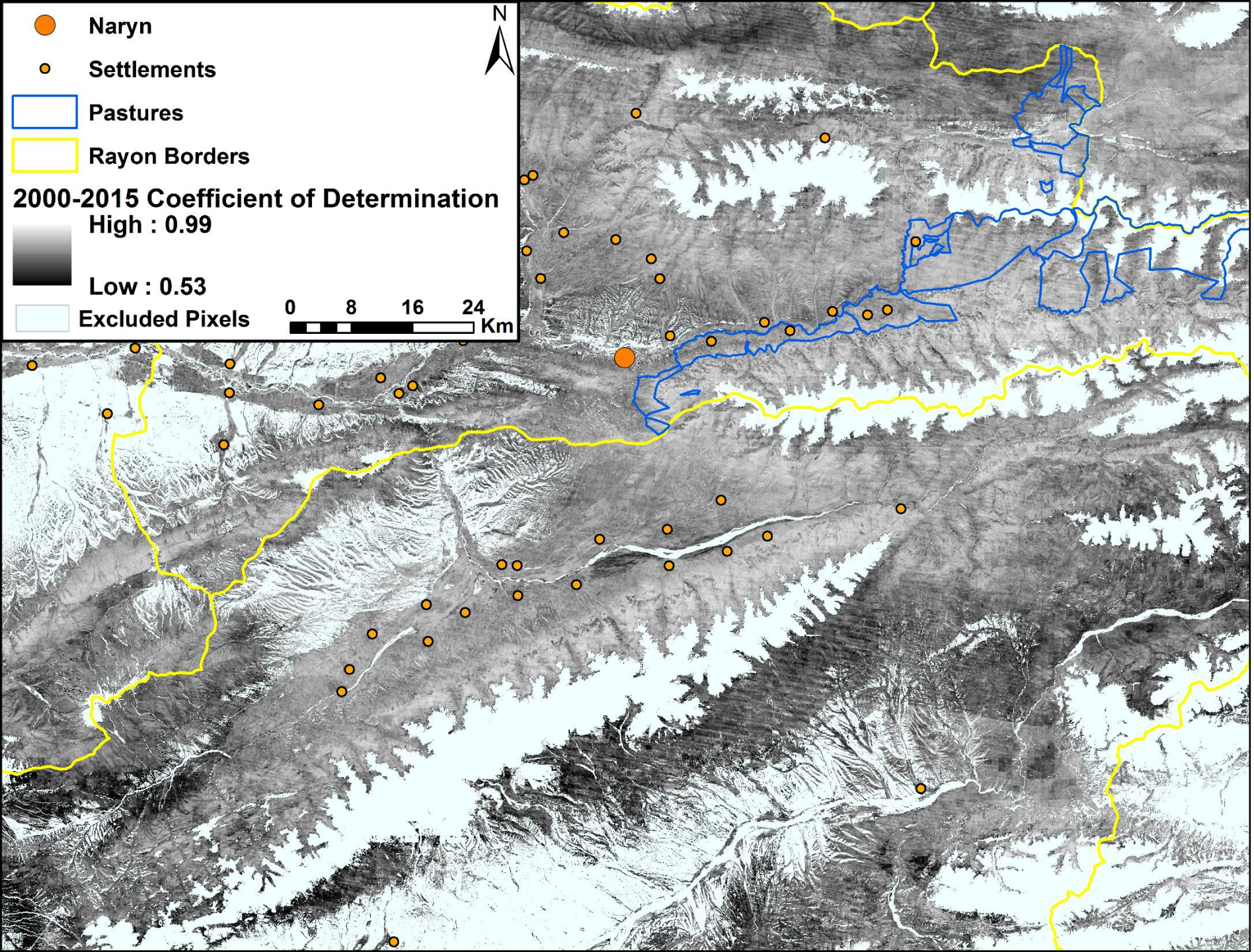


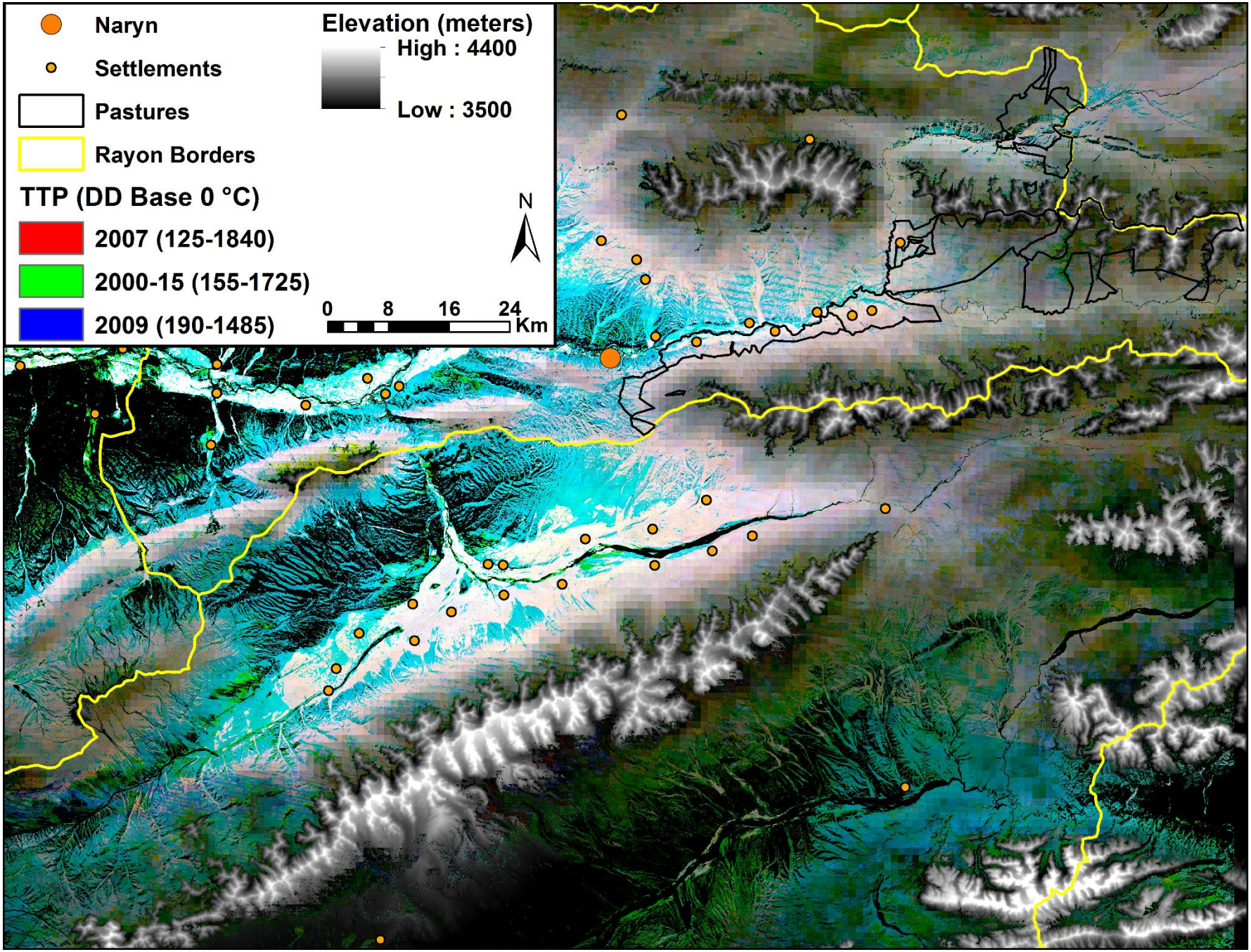
Krehbiel CP, GM Henebry. 2016. A Comparison of Multiple Datasets for Monitoring Thermal Time in Urban Areas over the U.S. Upper Midwest. ***Remote Sensing*** 8:297. http://doi.org/10.3390/rs8040297

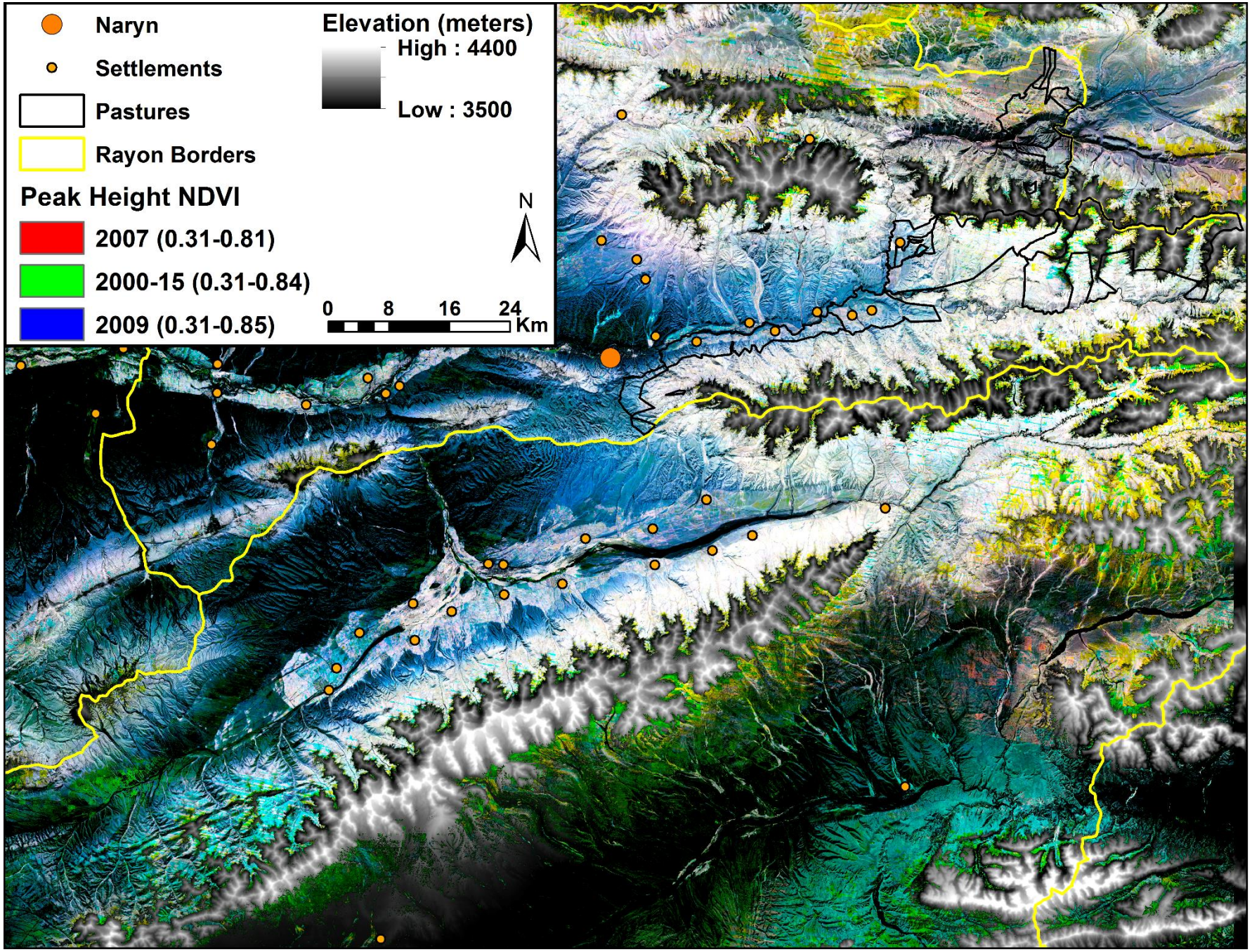

N
Legend
Naryn Region of Interest
Districts
Kyrgyzstan
'03-'15 Mean Annual AGDD
High : 7000
Low : 0
0
40
80
160
240
320
Km


Naryn
Settlements
Pastures
Rayon Borders
False Color Composite
2000-15 Mean TTP (100-2650 DD)
2000-15 Mean PH (0.3-0.9 NDVI)
2000-15 Total Years (0-16)
Elevation (meters)
High : 4400
Low : 3500
N
0 10 20 30
Km
>1500 Scenes: 2000-2015


Naryn
Settlements
Pastures
Elevation Transect
Aspect Analysis ROI
Rayon Borders
0 10 20 30
Km
2000-2015 PH (NDVI)
High : 0.99
Low : 0.0
Elevation (meters)
High : 4400
Low : 3500
N


Naryn
Settlements
Pastures
Rayon Borders
2000-2015 Coefficient of Determination
High : 0.99
Low : 0.53
Excluded Pixels
N
0
8
16
24
Km


Naryn
Settlements
Pastures
Rayon Borders
TTP (DD Base 0 °C)
2007 (125-1840)
2000-15 (155-1725)
2009 (190-1485)
Elevation (meters)
High : 4400
Low : 3500
N
0 8 16 24
Km


Naryn
Settlements
Pastures
Rayon Borders
Peak Height NDVI
2007 (0.31-0.81)
2000-15 (0.31-0.84)
2009 (0.31-0.85)
Elevation (meters)
High : 4400
Low : 3500
N
0 8 16 24
Km

Explaining the maps to members of the local pasture committee…

Enjoying Kyrgyz hospitality, including many cups of kumis …


Thank you!
18/7/2016 3:27